SCIENCE

FRIDAY, MAY 28, 1915

CONTENTS

MSS. intended for publication and books, etc., intended for review should be sent to Professor J. McKeen Cattell, Garrison-on-Hudson, N. Y.

DISEASE RESISTANCE IN PLANTS[1]

THE control of fungous diseases in plants may be effected in three different ways: (1) By killing the parasite before it enters the host, (2) by curing the diseased plants, and (3) by growing disease-resistant varieties of cultivated plants or making the susceptible varieties resistant. So far the first method is the one most generally followed, the means employed depending on the nature of the fungus.

It is easier to protect the host from a fungus which combines a highly developed parasitic character with alternation of hosts than from one which spends its entire life cycle on the same host. For example, when rust (*Rœstelia cancellata*) appears in a pear orchard the danger from it may be done away with by removing all juniper trees from the neighborhood, the juniper being the host for the alternate stage of the fungus (*Gymnosporangium sabinæ*). The same measure may be adopted in the case of red rust of wheat (*Puccinia graminis*) in countries in which the fungus does not reinfect directly the wheat but grows in the spring on the barberry (*Berberis*). This disease has practically disappeared from Germany since the removal of all barberry and mahonia bushes from the vicinity.

The destruction of a fungus living on one host only is more difficult because of the fact that this may necessitate the destruction of all diseased plants or parts of them, an undertaking which could hardly be carried out completely. However, if carried

[1] A lecture delivered by invitation at the universities of California, Wisconsin, Minnesota and Cornell, and the Iowa Agricultural College, in October, 1914.

out thoroughly and before the parasite has reached too advanced a stage of development this method may be crowned with success. A striking example of this is the control of pear blight in the Rogue River Valley, Oregon. In this region the disease has been kept within bounds, while in the Eastern States it was permitted to gain a foothold and is now a calamity.

The spraying of potatoes against *Phytophthora infestans*, by which the fungus is destroyed before it is able to penetrate the tissues of the host, may be included in this class of control measures. Another example is the destruction of the smut spores, which cling to the outer covering of the grain, in the case of stinking smut, for instance.

It is a more difficult task to cure a plant already diseased than to prevent the disease, and only in rare cases is the method of cure known, the reason for this being that plants are not organized like animals, and in most cases it is impossible to influence a central system. The cure of fungus diseases of different trees by giving the roots an abundant water supply is an example of treatment based on the principle that many fungi are unable to grow in tissues which show a high water pressure. In dry soils the water content is kept on a low basis and this favors the attacks of the fungus.

Another example of the curing of the plant is the hot-water method of seed treatment for loose smut of wheat and barley, this treatment being founded on the destruction of the fungus germs within the seed.

We now come to the third method of disease control, that is the use of disease-resistant plants. The importance of this method is well understood by both scientists and growers, but the application of the principle, it must be confessed, is in its infancy.

Utilization of the factor of immunity in disease control may be divided into two parts, that is the breeding of resistant plants and the artificial immunization of plants. From a scientific point of view, however, both of these rest on the same basis.

Before a disease-resistant race can be bred resistant individual plants must be found. It is a well-known fact that in the vegetable kingdom closely related species suffer in different degrees from attacks of the same parasite. The difference in resistance of the various species of one of our most important cultivated crops, wheat, is unusually prominent, as shown by the researches of Wawelow. Of the eight botanical species which are generally thought to have produced the cultural varieties of our wheat, *Triticum vulgare, T. compactum* and *T. spelta* are attacked by red rust; *T. durum, T. polonicum, T. turgidum* and *T. monococcum* are resistant; the western European varieties of *T. dicoccum* are resistant, and the eastern varieties of Turkestan are liable to rust. *T. dicoccum dicoccoides,* which was found in Palestine some years ago and which has sometimes been regarded as the ancestor of our common cultivated wheat, *T. sativum,* is also a non-resistant species.

The varying susceptibility of species of the same genus makes it possible to substitute for highly susceptible species others of nearly equal cultural value which are less susceptible or resistant. In the case of the coffee plant very good results have been obtained by this means. It is well known that *Coffea arabica* was completely destroyed throughout the Asiatic tropics by the rust fungus *Hemileia vastatrix.* The related African species *C. liberica* appeared to be resistant to the disease and was brought under cultivation in the entire territory in which *C. arabica* had been grown and in

which coffee culture was possible. The immunity of this variety, however, proved to be of an unstable nature, and as a consequence the growers were obliged to import *C. robusta,* a species having lower commercial value, from the virgin forests of Africa. Because of the fact that *C. liberica* produces beans of much poorer quality than *C. arabica* and *C. robusta* beans of a poorer quality than *C. liberica* their substitution was of restricted value, but it saved the valuable coffee industry in some regions from ruin.

The maintenance of profits with the inferior coffee is made easier by the degeneration of taste among civilized people—the result of standardization in all branches of life. The average man to-day lacks the faculty of determining whether his beef was cut from a Holstein or a Hereford, whether the fowl on his table was fed with barley or oats, whether a wine is natural or sugared, or whether the coffee he drinks is *C. arabica, C. liberica* or *C. robusta.*

Even though the value of the resistant plant is lower, as in the case of the examples cited, the possibility of improving the variety still remains. Two methods may be used toward this end, that is grafting a non-resistant on a resistant variety or crossing the two. The first was followed in dealing with *Phylloxera* of the vine in Europe. The European vineyardists grafted their own highly cultivated varieties on the roots of the American vine, which latter resists the attacks of the parasite, and in this way produced a vine combining the requisite wine-producing qualities of the European vine with the disease resistance of the American vine. In view of these facts it would seem easier to replace the European vine with the American, but this is not practicable, because under European conditions of climate it is not possible to prepare wine from American species. The grafted vine is only an imperfect substitute, because its life is of short duration and the labor of grafting makes its culture expensive.

As the grafted vines are heavy bearers, the disadvantages from their use are not felt as keenly in France, where the aim of the viticulturist is to produce large quantities of wine, as in Germany, which aims to produce "quality wines." The really first-class wines are produced from vines which are permitted to grow only a few grapes, and this, coupled with the fact that the quality of wine improves with the age of the vine, shows that the cultivation of grafted vines is more impracticable in Germany than in France.

Another method of improving disease-resistant wild species and preparing them for cultivation is illustrated in the case of sugar cane. In the eastern part of Asia this plant, especially the high sugar-producing varieties, is subject to the so-called sereh disease, the nature of which is still unknown. In British India, however, the wild resistant Chunee cane was found, but it had too much fibrous substance to be suitable for sugar-producing purposes. Several hundred crosses were made between it, on the one hand, and the Cheribon, on the other. As a result of this crossing, several hybrids were obtained which produce the maximum amount of sugar and are at the same time resistant to the disease. As sugar cane is propagated by using its vegetative parts, that is parts of the stem, these qualities can be readily preserved. Notwithstanding these favorable results, however, our experience with sugar cane has proved that its "immunity" is not permanent, but diminishes in the course of cultivation, and the same is true in the case of the two varieties of coffee mentioned, the disappearance of immunity in

these being relatively rapid. No guarantee of future disease resistance has been found in either the hybrids or in the wild species.

Not only do closely related species show a difference in susceptibility to disease, but varieties and races of the same species behave differently in this respect. An example of this is *Triticum dicoccum,* one variety of which, as already stated, is resistant to rust and the other non-resistant. Additional examples are *T. vulgare,* a few varieties of which are resistant; certain varieties of potatoes with reference to *Phytophthora infestans; Pinus sylvestris* with reference to *Lophodermium pinastri;* and other cultivated plants. This difference in disease-resistance between races of the same species is of far greater importance than the difference between two species, because generally there is greater similarity between the cultural value of the two races.

The occurrence of healthy plants among diseased ones is not absolute proof of the resistance of such plants, and therefore to make sure of the immunity of any special strain careful experiments are necessary. It is not enough to raise a number of plants of an apparently resistant strain in a certain place. The question of resistance should be investigated from the beginning on the broadest basis. One of the principal things necessary is to expose the resistant plants to the fungus causing the disease to which they appear to be resistant. In the case of fungi which live in the soil, such, for instance, as the fungus causing stinking smut, the first requisite is to determine whether they are present and, if not present, to introduce them, while in the case of fungi spread by the wind, such as those causing rust and mildew, the infection should be induced either naturally or artificially.

The presence of the fungus, however, is only one factor in the experiment. The second factor is the disposition of the host plant, that is, its internal qualities, which makes infection possible. The third factor is the coincidence of the infection period with the susceptible condition of the host. When all of these factors are present the possibility of infection is certain, and only under such circumstances will the results be reliable.

Fluctuation in the prevalence of fungous plant diseases is due to the presence or absence of proper conditions for the development of the fungi causing them. For instance, loose smut appears to a very serious extent in certain summers, and naturally it would be expected to be still more prevalent the succeeding summer. The fact is, however, that although spores in sufficient quantity to infect all the flowers in the field were scattered, the disease may be much less serious, the reason being that the plant was not in the proper stage a sufficient length of time to receive the infection, or in other words the weather conditions caused too rapid withering of the flowers to permit infection.

The effect of different conditions on the relation of host and parasite makes it necessary that investigations to determine the resistance of strains shall be carried on not only for a number of years, but also in different localities. Even under such circumstances the outcome may be uncertain. In many cases immune forms when cultivated prove to be only partly immune.

The best opportunity for finding immune strains is afforded by diseases which are of regular occurrence. In such cases it is possible to find with a degree of certainty forms which are immune in a certain locality, but while such experiments may give results of practical value, the

problem of immunity can not be solved in this way.

The third way to obtain immune forms is to select resistant individuals and from them breed pure strains. In the case of many diseases, although certainly not in all, healthy individual plants are found in the diseased plots, and the breeding of immune strains from these individuals would seem to be very simple, but experience has taught the contrary. All the factors pointed out in connection with the selection of immune forms must be reckoned with, but in a still greater degree. So long as the appearance of the disease is the only criterion by which to determine the susceptibility of the plants to disease the experimenter is exposed to all kinds of unknown influences.

Several attempts to breed kinds of wheat immune to stinking smut have been made without any real results. The question of producing such kinds is of great importance, especially for the United States. In the large wheat areas of Idaho and eastern Washington, for instance, stinking smut is very serious, not infrequently causing a loss of twenty-five per cent. of the crop. Inspection of seed in that state discloses the fact that a large part of it is covered with the smut spores, and treatment of the seed with copper sulphate is said to be useless because the soil is so badly infected. In many European countries, however, smut has been completely controlled.

In the case of smut the possibility of infection, as far as the fungus is concerned, is very great. As infected plants are in general not very productive on account of the seed being destroyed by the fungus, it might be supposed that smut-resistant plants would propagate well and that the strains would become immune. This, however, is not the case, and it shows that the breeding of smutless wheat by selection of healthy individuals has little chance of success, a fact which has been proved by experiments already made. That this is an impossibility, however, can hardly be stated definitely, but success could be obtained, if at all, only after tremendous amount of labor in breeding and trying hundreds of forms or by fortunate accident.

It will be remembered that Orton by this method of breeding succeeded in obtaining varieties of cotton and watermelon resistant to *Fusarium* wilt. As the original resistant individuals found in the field gave too small yields, he crossed them with prolific varieties and in this way combined the disease resistance of the one parent with the productivity of the other. A similar thing was done by Bolley with flax and by L. R. Jones with cabbage, both of whom bred wilt-resistant varieties by selection. In the case of wheat, it is the opinion of the writer that there would be better chance of breeding smut-resistant varieties if strains rather than individual plants were selected and crossed with productive varieties. Orton very successfully selected a certain variety of cowpea resistant to wilt disease and root knot, that is, the iron cowpea grown in South Carolina, and crossed it with a more desirable variety. By this means also, that is by selecting certain varieties, some of the *Phytophthora*-resistant varieties of potatoes were obtained, and probably also the square head wheat which shows immunity to *Puccinia triticina*.

Next to field experiments, those in the laboratory might aid in the discovery of resistant varieties of cultivated plants. Such experiments have advantages over those in the field and are practical in case of diseases caused by parasites that may be grown artificially in pure cultures.

The greatest advantage of the laboratory experiments is that in them the experimental plants may be infected at any time and under any conditions. The plants may be kept dry or wet and under different temperatures, they may be fed in different ways, and the factors of growth may be influenced within wide limits. Under such conditions the optimum of infection may be determined for different varieties.

The results of laboratory experiments frequently differ greatly from those of field experiments. For instance, in Wawelow's field experiments *Triticum durum, T. polonicum* and *T. turgidum* were resistant to *Erysiphe graminis,* but in his greenhouse experiments they became infected with this disease. Reed's experience in this respect was similar to that of Wawelow. It is the opinion of the writer that the host plants were strongly influenced by circumstances, but Wawelow attributes the different results to favorable conditions in the greenhouse for the development of large quantities of conidia.

Such unbalancing of the host is not infrequent and in the natural environment is due to extreme weather conditions. Some species of *Ribes* are known to be immune to the æcidium of the pine blister rust (*Peridermium strobi*), but these species may be infected and form æcidia under a bell jar. In the field the leaves are infected, this being shown by the development of slight yellow patches, but the æcidia never appear. The same is true in the case of some varieties of wheat with regard to *Puccinia,* according to Fraser, on account of the thickness of the cuticle. This partial immunity is satisfactory for practical purposes, and while partially immune plants suffer in a small degree through reduction of the assimilating surface, they do not increase the danger of spreading the rust, as they form no new sources of infection.

Although some very profitable results have been obtained, as already shown, from the immunity methods discussed, the problem of immunity should be solved in a different way. Immunity must not be regarded as the only definite point to be studied. In the case of every special disease efforts should be made to determine the causes of resistance. That immunity from different diseases is due to different causes is clear and the factors which determine this must now be sought.

The cause of immunity of wheat and barley from loose smut is among the simplest. From the investigations of Hecke and Brefeld it is known that the smut spores are carried by the wind to the stigma and that there they germinate and find their way to the ovule through the pollen tubes. As is generally known, there are varieties of wheat which have closed flowers, which means that fertilization takes place within the glumes. In such cases the smut spores can not reach the stigmas at the proper time, and therefore infection can not take place. In this case, therefore, by investigating the question of flowering the problem of resistance can be solved without artificial infection. Many of the intermediate stages which exist between immune and susceptible races may be detected by close observation. In like manner several races of rye show different degrees of susceptibility to ergot (*Claviceps purpurea*), the resistance being least in those having a long flowering period.

The channel from the calyx to the carpels is open in many varieties of pears. Such varieties are susceptible to infection by *Fusarium putrefaciens,* as Osterwalder has shown. The varieties without the open

channel are protected against this means of infection.

The habitus of a plant may influence its disease resistance. An instance of this is the potato with reference to the late blight (*Phytophthora infestans*). Infection of the potato vine with this disease is caused by the conidia being carried to the leaves by the wind. The conidia remain on the leaves until a drop of water causes them to liberate their zoospores. These swim around in the water for some time, then drop their cilia, germinate, and send a hypha into a stoma. Passing through a potato field shortly after a heavy rain, it will be observed that the leaves of some sorts dry within half an hour, while others remain wet for several hours. Generally the quick-drying varieties are less susceptible to the disease than the slow-drying varieties. Slow drying is the result of the plant's habit of growth, which hinders the evaporation of the rain drops. Such plants have flat leaves. Small, hairy leaves, as well as an airy, open growth of the whole plant, facilitate drying. It is possible that the arrangement of the stomata also may exert an influence on the attack of the fungus.

In the case of the grape leaf the arrangement of the stomata is of great importance. For a long time it was not known why spraying with Bordeaux mixture did not, in all cases, prevent the attack of *Peronospora*. Finally, however, Ruhland and Müller-Thurgau explained this by showing that in the grape leaf the stomata are formed only on the under surface. Spraying of the grape, therefore, can be effective only when the spray mixture reaches the under surface of the leaves, and this fact must be borne in mind when dealing with fungi which enter the leaf through the stomata. A similar thing was observed by the writer's assistant, Dr. Pietsch, whose investigations have not yet been published. He found that the resistance of some Remontant carnations is due to the form of the stomata, which makes it impossible for the hyphae to penetrate them. In some cases, however, the hyphæ can not produce infection even though they penetrate the stomata. In the case of cereals immunity from rust is independent of the stomata.

In cruciferous plants the water pores are the avenues of entrance for many bacterial diseases. The relation between their form and disease resistance, however, has not yet been established.

As may be seen in the case of the potato, the lenticels as well as the stomata may influence immunity. The scab fungus (*Oospora scabies*) after penetrating into the outer layers of the potato establishes itself in the lenticels and causes the surrounding tissues to produce an abnormal corky growth. Bacteria also may enter the lenticels, especially when on account of moist conditions the tissues are forming callus. This callus, however, does not form a sufficient protection, and softened tissue and even decaying spots result.

The lenticels are developed very differently in different varieties of potatoes, and it is therefore important that the relations between them and resistance to scab and bacterial rot be investigated.

The condition of the cuticle may influence infection, as shown by the behavior of cereal seedlings in resisting smut diseases. Such influence, however, is possible only in the very early stages of the seedlings' growth, that is before the tissues have attained full development. Since the germination tubes of smut are able to dissolve cellulose, there must be stored substances which cause resistance, and in this connection silicic acid is probably the first to suggest itself. Indeed the quantity of

this substance is different in seedlings of different kinds. Sorauer found resistance of different carnations to be due to thickness of the cuticle. It might be caused also by the wax layer, which is present in *Gramineæ*, carnations, and other plants.

In his experience the writer found that the wax layer influences the attack of *Coniothyrium* on raspberries. In a large horticultural establishment varieties which were covered by a thick blue wax layer were free from this disease, while other varieties were completely killed. The wax layer may exert its influence in different ways, that is it may prevent direct penetration by the hyphæ or it may act indirectly by causing the moisture to run off the plant. This was observed by the writer in making sprayings with Bordeaux mixture. In the case of plants covered with the wax layer the mixture ran off quickly and left no moisture. Conflicting results have been obtained from observations of *Glœosporium venetum* on raspberries on the fruit farm of the University of Minnesota. There is no difference between raspberries with wax and without wax. *Glœosporium venetum*, however, has very sticky conidia and is held by the wax layer, while *Coniothyrium* spores are washed away.

The hairs on the surface also play a part in this connection. Their unfavorable influence in the case of potato late blight has already been mentioned. A very interesting case of hair-like structures is found in the pea family. In some varieties the seeds are imbedded in a woolly outgrowth of the inner epidermis of the pod. Frequently when pods are infected with *Ascochyta pisi* the fungus penetrates into the interior. In varieties without these hairs the seeds are infected only when they are directly in contact with an infected spot of the pod. But when the interior is covered with the woolly outgrowth the fungus grows as in a culture medium and infects every seed.

The cork, which is without doubt a protecting tissue, is a definite kind of epidermis. The writer has never seen branches of cork elms attacked by fungi, but the common elm is subject to the attacks of several species. In the case of the potato the cork layer has the greatest significance.

The causes of the protecting action of the cork, however, may be different. Certain fungi are able to penetrate this cork layer, such as *Phytophthora*, and probably *Fusarium* and *Spondylocadium*. But the last-named fungus is able to penetrate only the very outermost layers of the potato, where it forms mycelium and sclerotia normally. Whenever it grows into the tissues below it must use the channels already opened by other fungi which may happen to be present. Thick cork layers seem to be impenetrable for *Phytophthora* and *Fusarium*. The questions involved are very difficult to solve, because it is hardly possible to judge whether a cork layer is intact or not.

As small wounds occur very generally, the rapidity with which wound cork is formed is possibly of more importance than the absolute thickness of the cork layer. In the course of work with black leg of the potato the writer was able to study this question. It is easy to cure a bacterial infection artificially. The potato is able to close a wound within a short time by the formation of cork. When the growth of bacteria is diminished by low temperature or drought the potato closes wounds more rapidly than the bacteria can penetrate. The ability to form wound cork varies in different varieties of potatoes. Some varieties begin cork formation within six hours after the wound is

inflicted, while in other varieties it is not begun for forty-eight hours or more. From this it is clear that the former may withstand infection better than the latter. By means of these experiments the relation between the structure of the plant and its bacterial resistance has been established beyond doubt. A similar relation, however, does not exist in the case of fungous diseases, as the fungi may penetrate the newly formed cork.

All the instances cited illustrate the influence of mechanical means of protection. But the plant also often escapes disease by means of rapid growth. A microscopic examination of seedlings attacked by smut shows that a number of seedlings may be infected, and yet only a few of the plants will show the disease, proving that the infection has been suppressed in many cases. In this connection attention is called to the fact that in the case of both stinking and loose smut the infection originates in the seed. The fungus mycelium grows in the seedling, but by rapid growth the latter may outstrip the fungus, which remains in the base of the plant and is harmless.

There are still other factors in plants which may influence resistance but which are not perceptible through the microscope. They may be found by physical or chemical research because they are based on the difference of contents. Probably these factors are of far greater importance than those already discussed. But till now these questions are far from being treated in an adequate manner. The foremost reason for this may be that here we have to deal with chemical substances such as albumens, tannins, etc., and there are few botanists who possess the necessary chemical knowledge to undertake such experiments. A bridge, therefore, must be built between botanists and chemists, and the latter's interest in this question awakened.

One of the best investigations made in this direction up to this time is that of Münch on the immunity and susceptibility of trees. He has shown that susceptibility of woody plants to fungous diseases depends on the quantity of water and consequently on the quantity of air in the wood. This is in accordance with the writer's experiments with *Rhizoctonia* and *Fusarium* which have shown that these fungi also have a high air requirement. In the United States, with its large areas of irrigated land, this fact is of great importance. It is possible that the influence of both of these fungi may be diminished by thorough regulation of water conditions.

A glance at sugars and acids shows that these substances also exert an influence in disease resistance. The presence of benzoic acid in *Vaccinium vitisidæa* is supposed to be the cause of its resistance to fungous diseases. In the same way the tannins have a relation to resistance. This was shown by Behrens in his work on fruit decay and confirmed by Cook and Taubenhaus. On the other hand, sugar favors the growth of fungi, as is shown clearly in the case of apples and pears. Henneberg even claims immunity for some varieties of potato from certain diseases on account of their high sugar content, but this has not been established beyond doubt.

Finally the enzymes exert a definite influence on immunity, the oxydases taking the lead. These ferments work directly or indirectly by producing resistant chemical substances.

This paper, it is believed, gives sufficient idea as to how, in the opinion of the writer, the problem of disease resistance should be dealt with in the future. The present methods should by no means be abandoned, for practical experience and happy accidents may help a great deal, but in addition to carrying out these methods an ef-

fort must be made to establish scientific fundamentals for new investigations. Efforts must be made to find the causes of immunity, and after solving this question to determine without infection the disease-resistant qualities in different varieties and individuals in order to be able to establish the desired resistance and at the same time eliminate undesirable qualities. It is only by working along this line that the breeding of disease-resistant varieties on a scientific basis can be accomplished and results which lie within the limits of possibility obtained.

OTTO APPEL
KAISERLICHE BIOLOGISCHE ANSTALT,
BERLIN-DAHLEM

THE CAVERN OF THE THREE BROTHERS (ARIEGE)

FOR the third time in less than three years it has been the good fortune of Count Begouen of Toulouse to announce the discovery of important works of art left by paleolithic man on the walls and floor of Pyrenean caverns. His two previous discoveries were noted at the time in the columns of SCIENCE.[1]

Quaternary art objects may be classed under two heads: the portable and the stationary. The portable class includes in part carved tools, weapons and ceremonial objects, such as poniards, spear throwers, bâtons, etc. It also includes engraved pebbles as well as carved fragments of stone, bone, ivory and the horn of stag and reindeer; in fact, almost anything that could be seized upon to satisfy the exuberant demands of the cave man's artistic impulse.

Stationary art embellishes the walls and ceilings of caverns and rock shelters. In rare instances the fine clay of the cavern floor was utilized for sketching and modeling purposes. The scientific world has been more or less familiar with the portable class of troglodyte art for more than half a century. Our acquaintance with the stationary art is of more recent date. The first discovery of this kind was made by Sautuola in 1879 at the cavern of Altamira in northern Spain. The scientific world, however, did not grasp the real significance of Sautuola's discovery until, after the lapse of nearly twenty years, similar finds had been made in France.

All three of Count Begouen's discoveries have to do principally with cave art of the stationary kind. In July, 1912, near his country estate of "Les Espas," which is only a short distance from Saint-Girons (Ariège), he found a series of subterranean galleries and connecting corridors opening out of an underground stream bed. On the walls of one of the corridors were several engravings of the horse, reindeer, mammoth, etc. Five days later it was the privilege of the writer to see this prehistoric gallery, called Tuc d'Audoubert, in company with Count Begouen and his three sons.

In October of the same year Count Begouen and his sons succeeded in gaining entrance to an additional gallery of the series, but not until after they had broken down two stalagmite pillars that blocked the narrow passage way. What they found there has already been described. The most notable objects were two figures of the bison modeled in the clay of the cavern floor. They owed their preservation to the accidental sealing up of the gallery ages ago by the stalagmite pillars. In view of their excellence, it is probable that they are not unique examples; that perhaps other similar figures less fortunately situated have been destroyed because the artist did not know how to temper and fire his product.

The need of something less difficult to manipulate than stone, bone, ivory and horn must have been ever present in the experience of the troglodyte artist; it is not strange therefore that he should have finally hit upon clay. This illustrates how near an individual or a race may come to some great discovery and yet fall short of it. Thus was the discovery of the ceramic art left to the later more practical, if less artistic, neolithic races.

The latest discovery of Count Begouen and

[1] N. S., XXXVI., pp. 269 and 796, 1912.